BBAA VI International Colloquium on:
Bluff Bodies Aerodynamics & Applications
Milano, Italy, July, 20-24 2008

COMPARISON BETWEEN FIELD MEASUREMENTS AND NUMERICAL SIMULATIONS OF THE WIND SPEED ALONG THE HS/HC ROME-NAPLES RAILWAY LINE

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Keywords: Railway line, Wind Probabilistic Analyses, Risk Assessment, CWC.

1 INTRODUCTION

In last decades, the need of faster transports by land drove to develop high-speed trains that stand out not only because of excellent aerodynamic characteristics, but because of very light weight as well. Consequently, they became very sensitive to the action of cross-winds. A commonly used tool for the evaluation of the safety against vehicle overturning due to high wind gusts is provided by the Characteristic Wind Curves (CWC). They are evaluated in wind-tunnel tests, and they furnish the maximum allowable train velocity depending on the wind speed and direction at the railway line. The definition of the probabilistic distribution of the wind speed and direction along the railway lines is then fundamental to provide a reliable risk assessment. For this purpose, a new methodology has been developed for the evaluation of the wind speed along any railway line and to any context. Its current application deals with the Rome-Naples High Speed (HS)/High Capacity (HC) railway line in Italy (Figure 1); it is based on the probabilistic assessment of long-term measures carried out by the meteorological stations of the Italian Air Force (AF) and of the company that provides servicing to air traffic in Italy (ENAV) in Lazio and Campania regions (Figure 1).
The developed method can be summarized in four main steps: A) line, stations and territory modeling; B) wind simulation; C) probabilistic assessment; D) comparisons and methodology assessment. Each step is organized in sub-steps as shown in Figure 2. The early 3 points of the method, presented in [1] and in other papers currently in progress, leads to the evaluation of the mean and peak wind speed at any point of the line, taking into account also the local features of the ground (e.g. embankments, cuts and viaducts). The present study is focused on the comparison between the probabilistic analyses carried out on the data collected by

anemometers placed by Rete Ferroviaria Italiana (RFI) along the line (Figure 1) and those obtained along any point of the same line through the application of the new methodology.

Figure 1: Railway line, AF/ENAV stations (indicated by names) and RFI monitoring system (stations indicated by numbers).

2 PROBABILISTIC ANALYSIS OF THE WIND SPEED FROM LONG-TERM MEASUREMENT STATIONS

The HS/HC railway line links Rome and Naples in central-southern Italy (Figure 1). It is 196 km long and winds along a terrain characterized by complex orography. Seven meteorological stations close to the line have been selected to perform this study, with data available for periods between 44 and 54 years. A digital model has then been realized that involves the soil topography, the soil roughness and the displacement level of the whole area surrounding the railway line and the meteorological stations. The digital model has been used to perform the numerical simulation of the mean wind fields in the area by using the mass-consistent model WINDS [2]. In this way the transmission coefficients, i.e. the parameters expressing the change of the wind speed and directions at different locations, have been evaluated from the stations to reference conditions (i.e. open and homogeneous flat ground with roughness length equal to 0.05m) and then from reference conditions to the railway line, at a height equal to 3m above the ground (i.e. 2m above the track). The passage to reference conditions has been adopted to make the data of the stations more homogeneous, and then to allow a former comparison of the results of the probabilistic analyses before the projection of the databases to the line. Thanks to the transmission coefficients, it became possible to transfer the databases of the anemological records from each stations to any point of the line, and to submit them to probabilistic analyses. The parent population has been regressed by using hybrid Weibull model. The extreme distribution has been obtained by means of three alternative methods: the asymptotic model of the first type (Gumbel distribution), the POT Pareto technique and the process analysis. The process analysis has also been implemented to avoid biased values due to discontinuous acquisitions, missing data and wrong wind calms. The final distributions of the wind speeds and directions along the line are expressed as a weighted average of the distributions of the wind speeds and directions associated with the different stations through appropriate weighting coefficients. The whole sequence, reported more in detail in [1], is depicted in Figure 2.

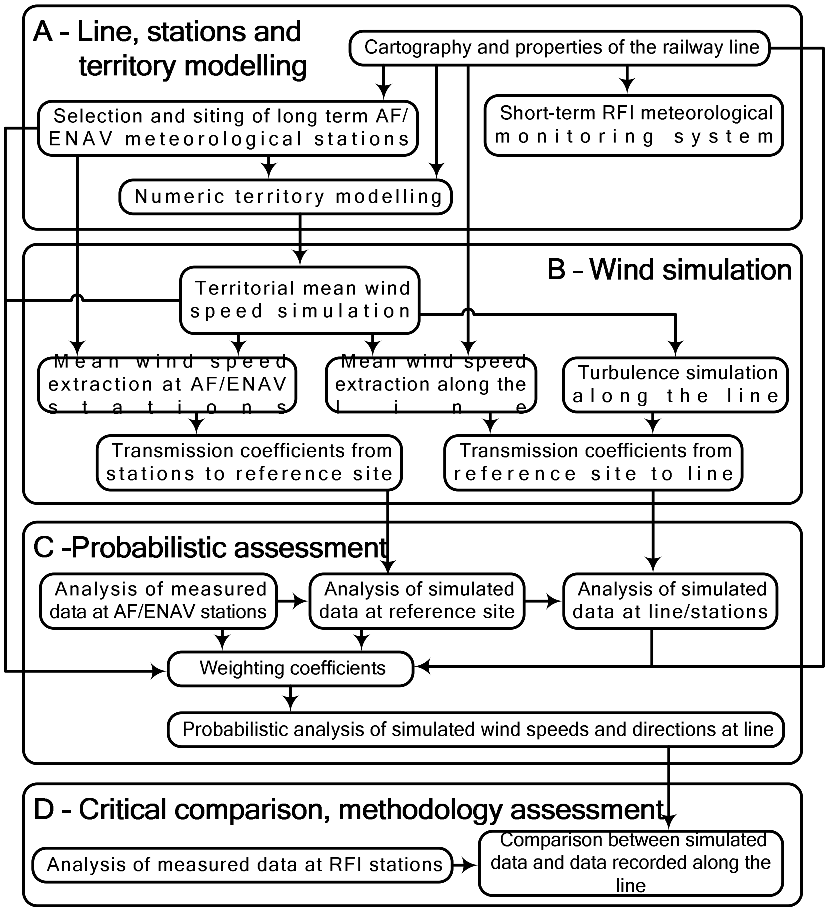

Figure 2: General scheme of the procedure adopted for the probabilistic assessment of the wind speed.

3 PROBABILISTIC ANALYSIS OF THE WIND SPEED MEASURED ALONG THE RAILWAY LINE

Besides long-term anemometric measurements, this study avails of short-term measures carried out by the network realized by RFI along the line. Figure 1 shows the position of these stations along the railway line. The anemometers are placed at 3 m height above the ground level (i.e. roughly 2 m over the track), and on several different locations: embankments, cuts and viaducts. The analysis of the data is used to check and up-date the probabilistic analyses introduced in the previous section and – in the meantime – for the realization of a now-cast and forecast system. The network includes 11 stations; each station registers continuously the mean value, the direction, the standard deviation, the minimum and the maximum value of the wind speed over 10 minutes. This data is available beginning from January 2006, and for this reason only the regression of the population of data has been carried out. More details about the short-term measurement system will be presented in the extended version of the paper.

4 COMPARISON BETWEEN SIMULATED AND REGISTERED DATA

The agreement between recorded and simulated data is variable. Figure 3 shows, for the RFI station 7658, the comparison between the mean wind velocities with assigned exceedance probability (equal to 0.01 and 0.001) obtained from the analysis of the data recorded along the line and those obtained by numerical simulations. In this case the comparison shows a very good agreement, that is not achieved for all the stations. Several reasons can be adducted to explain the differences between numerical simulations and field measurements, though. It should be borne in mind that the mathematical models at the roots of numerical simulations loose reliability when approaching the soil, and in any case close to obstacles. The extraction of wind speed at a reduced height above the ground implies that the model is operating in a limited-confidence region. On the other hand, RFI anemometers are placed at 3 m above the ground, often in areas with complex orography and high roughness length, and therefore their measurements are rather conditioned by local ground characteristics. Last but not least, the mass-consistent model WINDS can process correctly winds at the synoptic scale, but not local events like daily breezes, thunderstorms and phoen winds. Several local phenomena can be found in data recorded by RFI anemometers instead.

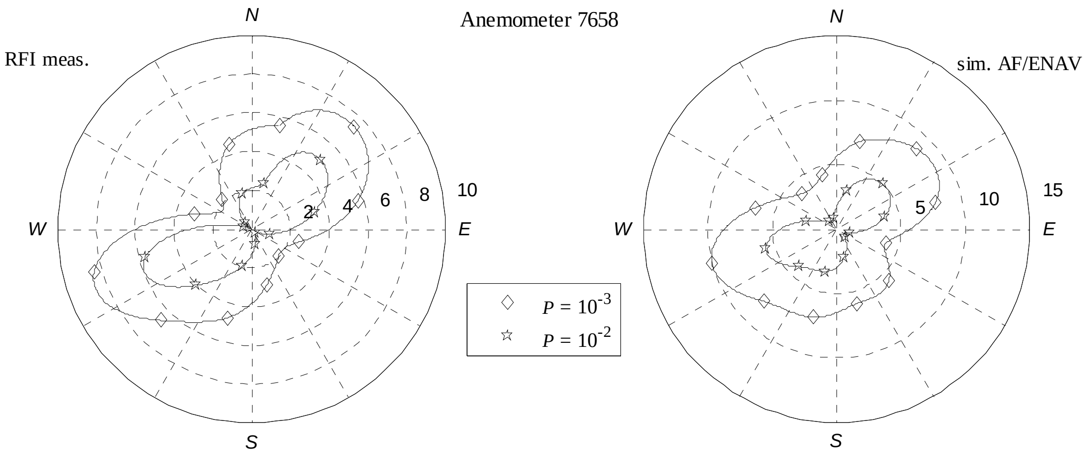

Figure 3: Comparison between the wind velocities with assigned exceedance probability obtained from the analysis of the data recorded along the line (left panel) and those obtained by numerical simulations (right panel).

5 CONSIDERATIONS AND CONCLUSIONS

The procedure adopted to derive the aforementioned method is rational, and it makes use of advanced tools; this notwithstanding, there are several uncertainties in the sequence that leads to the evaluation of the probabilistic evaluation of the wind speed and direction at the railway line. Such uncertainties are related to the numerical modeling (e.g. the land cover model does not take into account the changes that might be happened over roughly 50 years), to the extraction close to the ground of the wind speed from simulations and to the position of the anemometers along the line, that are positioned at 3m above the ground and therefore strongly influenced by local features of the neighboring terrain. A critical approach to the uncertainties involved in the method – aimed at a global assessment of the method and at establishing how the short-term measurement system might be enhanced – is presented in the extended version of the paper, highlighted by more comparisons between simulated and registered data at the line.

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